NASA TN D-1853

NASA TN D-1853

29 p.

N63 18661

CODE-1

TECHNICAL NOTE

D-1853

ACHIEVING SATELLITE RELIABILITY THROUGH ENVIRONMENTAL TESTS

John C. New
Goddard Space Flight Center
Greenbelt, Maryland

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON July 1963

ACHIEVING SATELLITE RELIABILITY THROUGH ENVIRONMENTAL TESTS

by

John C. New

Goddard Space Flight Center

SUMMARY

18661

The principles, policies, and procedures used by NASA in achieving satellite reliability by exploiting environmental testing techniques are described. The formalized environmental test plan for a typical satellite program is reviewed to illustrate these objectives. A discussion that highlights the reliability objectives of space missions as contrasted with military or industrial missions is given. Actual experience gained by utilization of this program is shown by results obtained with several scientific satellites that have been successfully orbited.

CONTENTS

ACHIEVING SATELLITE RELIABILITY THROUGH ENVIRONMENTAL TESTS*

by

John C. New

Goddard Space Flight Center

INTRODUCTION

Perhaps no venture in history has so completely captured the attention and resources of the peoples of the world as the series of events now unfolding as the *Space Age*. Also, there is probably no age in history–the supersonic age, the jet age, or the automatic age notwithstanding–that ultimately could be as important to each of us, either as individuals or as nations.

The *Space Age* was ushered in October 4, 1957, with the dramatic announcement by the USSR of the successful orbit of Sputnik I (1957 α 2). Since that date, 150 space systems–including Vanguards, Explorers, Cosmos, Pioneers, Luniks, Vostoks, Discoverers, Mercurys, Mariners, Tiros–have been successfully launched. The U. S. program has placed an estimated 167,000 pounds in orbit, in contrast with the 250,000 pounds estimated for the USSR program. A summary of space activity is presented in Table 1.

The Echo passive satellite has been sighted by millions; television programs have been relayed across the Atlantic by Telstar; astronauts of the Mercury program have seen six sunsets in less than a day; Mariner has probed the Venus atmosphere and established a communication distance record in excess of 50 million miles; and Tiros has faithfully produced weather pictures that have saved countless lives and millions of dollars by timely warnings of hurricanes alone.

These achievements don't belong to any single group. They are a product resulting from the industrial, governmental, and academic communities working together as partners in a gigantic technological race. Great impetus was given to this program when President Kennedy set forth the national goal of landing a man on the moon and returning him safely *within this decade*. By authority of the Space Act of 1958, the resources of this nation have been organized under the direction of the National Aeronautics and Space Administration (NASA) to implement the space program for the peaceful

*Presented at the Institute of Environmental Sciences, Los Angeles, April 17-19, 1963; also published in Proceedings.

Table 1
Space Activity Summary (as of Dec. 31, 1962).

Spacecraft Orbited	Earth Satellites	Manned Spacecraft	Lunar Probe	Interplanetary Probe	Total
U. S.	115	3	1	5	124
USSR	18	4	1	3	26
Totals:	133	7	2	8	150

benefit of mankind. Total expenditure for this space effort through calendar year 1962 is estimated at $8 billion. The cost of space activities during 1963 will approach nearly 1 percent of the gross national product. While it is difficult to assess costs in a research and development program, dollar economy must never be overlooked. For example, the cost of a typical 200-pound scientific satellite in orbit, when launched by a Thor-Delta vehicle, is about $10 million. Thus, the cost per pound is about $50,000.*

SPACE SYSTEM DEFINED

Before proceeding, it is desirable to define just what is being discussed. In the unmanned exploration of space, three systems are usable: the sounding rocket, the earth satellite, and the space probe (identified in Figure 1). A space system is composed of a launch vehicle or booster that lifts the payload–spacecraft or satellite–to the desired altitude. At this point the spacecraft or probe is injected into an earth or sun orbit by means of a final stage that imparts the necessary kinetic energy to maintain the orbital or escape velocity. The main functions occurring during this trajectory are shown in Figure 2. The spacecraft, which has shed its protective shroud after leaving the atmosphere,

*Earlier estimates, Reference 1, had cited this figure at $67,000 per pound.

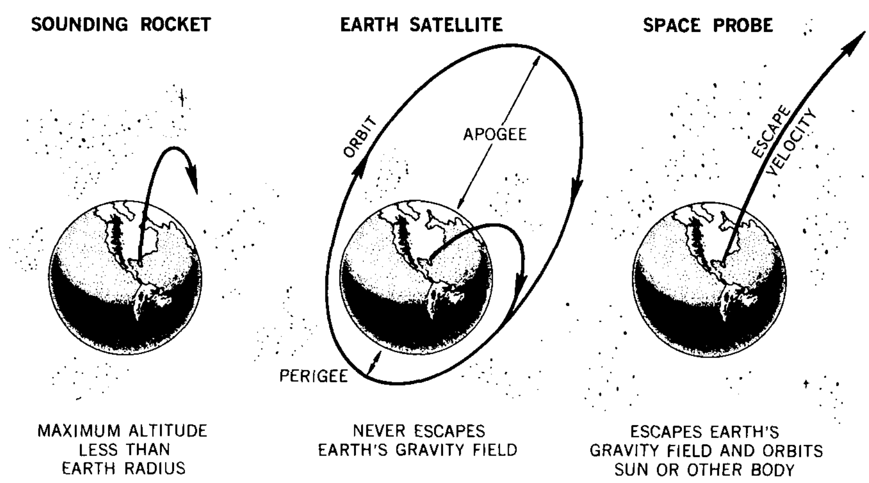


Figure 1—Space exploration.

is composed of a structure, power supply, telemetry system, interface hardware (such as cabling, connectors, junction boxes, etc.), and the prime payload—the scientific experiments; these elements are shown in Figure 3. The distribution of weight is shown for five different satellites in Table 2. A satellite typical of the second generation observatory class is shown in Figure 4.

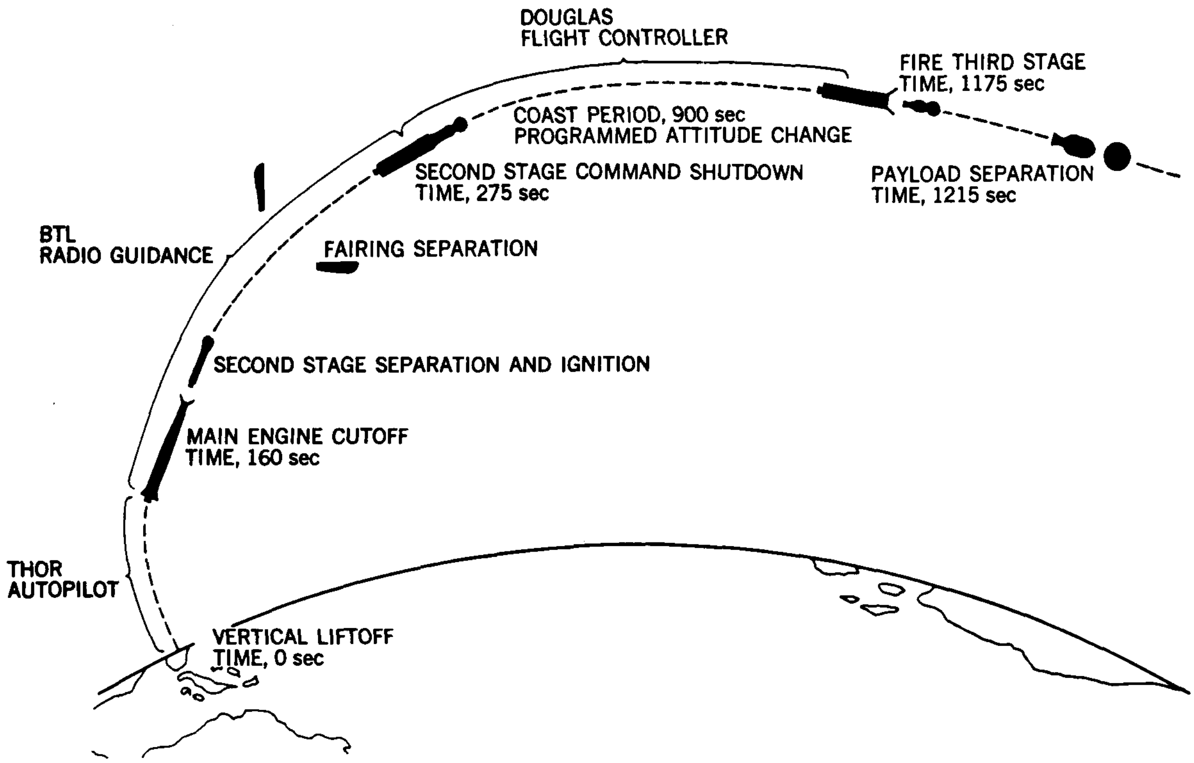


Figure 2—Typical launch sequence for Thor-Delta vehicle.

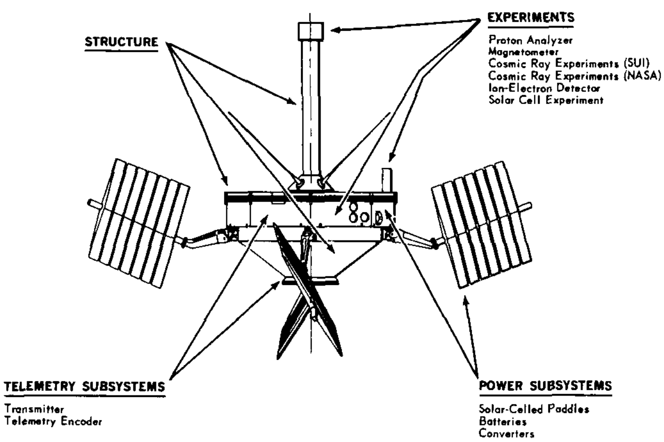


Figure 3—Elements of a spacecraft.

Table 2

Weight Distribution in Percent for Spacecraft.

Item	Spacecraft Weight (lb)				
	97	125	145	275	1000
Structure	28	20	28	22	20
Telemetry	3	3	11	7	13
Power supply	33	35	23	35	20
Interface hardware	20	14	7	19	17
Experiments	16	28	31	17	17
Guidance and control	--	--	--	--	13

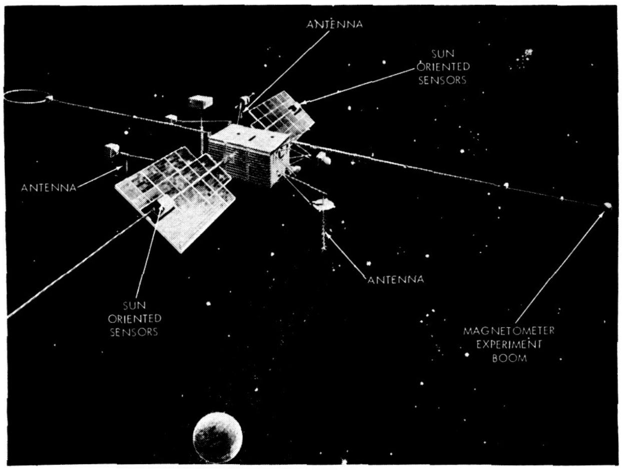


Figure 4—Orbiting Geophysical Observatory.

A spacecraft or satellite is a very complex system. It is primarily electronic in nature, since all actions must be effected through radio commands. A scientific satellite might include 1000 transistors, 1500 diodes, 5000 passive components (resistors, capacitors), and 8000 solar cells. It must be capable of "unfolding" in space large antennas, solar paddles, and remote positioning booms. The structures might extend from a few feet to several hundred feet. In addition, there are precise and exacting "laboratory type" instruments—Geiger counters, photomultipliers, mass spectrometers, precision optics—all of which must operate without benefit of human hands.

Perhaps we now have a basis to consider the extreme importance of satellite reliability and the complexity of the quality assurance problem. Factors that vitally affect this effort are:

The high unit cost of each launch

The small quantities involved—no mass production

Impact on national prestige

Complexity of spacecraft

Consequences of launch blowup

Lack of environmental knowledge

Use of unproven hardware in a new design application

Flight readiness at specific periods for orbital, rendezvous, or planetary operations

The achievement of high reliability with such diverse factors requires an intensive effort and demands near-perfection in materials, design, management, manufacture, assembly, test, and launch. And *PEOPLE* must produce this perfection.

THE RELIABILITY PROBLEM DEFINED

The reliability problem is easy to cite. But just what is it? Is it a fad, a figure, or a fancy way of saying something else? The accepted definition for reliability of a given system is:

The PROBABILITY of performing the REQUIRED FUNCTIONS under

DEFINED CONDITIONS for a specified PERIOD OF TIME

The four key elements of this definition are probability, success, environment, and time. We will examine the meaning of each element as it applies to the space program.

Probability

This element cites the degree of success desired, or the number of failures permitted — or the mean time between failures. It describes how well the system must work, or it is a measure of one's confidence in a system's performing as designed. This probability is more of a goal than an established fact. Specific values depend on missions as well as systems. For example, a higher reliability is demanded of a manned mission to the moon than for a Venus fly-by or for an unmanned Orbiting Solar Observatory. Specific probabilities for space missions are difficult to assign. A goal of 0.95 is commonly used or, stated differently, the risk of failure should not be greater than 1 in 20.

It is interesting to compare the requirements for a military missile weapon system and the orbiting of an unmanned spacecraft: In both systems the reliability of the launch vehicle should be as high as possible. The required function of the missile system is the detonation of a warhead in a defined target area; the required function of the spacecraft is the transmission by radio telemetry of encoded scientific data. The overall success of the missile system (target-kill) can be enhanced by multiple launchings; in contrast, failures in the spacecraft simply mean loss of the scientific data. The weapon system must be capable of being launched on demand; the spacecraft, within limits, can wait "favorable conditions" and can be protected from adverse climatic conditions — it generally can be given the "white-kid-glove" treatment.

Required Functions

The operation of a scientific satellite after it is injected into orbit depends on the mission requirements. In a general way, the required functions consist of sensing some space characteristic (e. g., electron density, energetic particle, solar radiation, or micrometeorite), converting the characteristic to an electrical signal, encoding several such signals, and telemetering the encoded signal to Earth. In addition there are requirements for temperature regulation, spin-up attitude sensing, and perhaps pointing control. It is not an easy task to define these required functions in terms of success or failure; they seldom are either black or white. The recovery of the information signal from the noise is a challenging task requiring a complex of electronic computers.

Environmental Conditions

The general environmental categories that a satellite encounters may be categorized as: (1) prelaunch, (2) launch, (3) orbit, (4) planetary dwell, and (5) atmospheric entry.

A significant design factor for a satellite is that careful control of the environment can be exercised under category (1), but beyond that category the full range of conditions must be considered. As would be expected, the general configuration of the spacecraft may be different for each of the categories cited. The several environments to be encountered are shown in Figure 5. Some quantitative values for the cislunar space environments are shown in Figure 6.

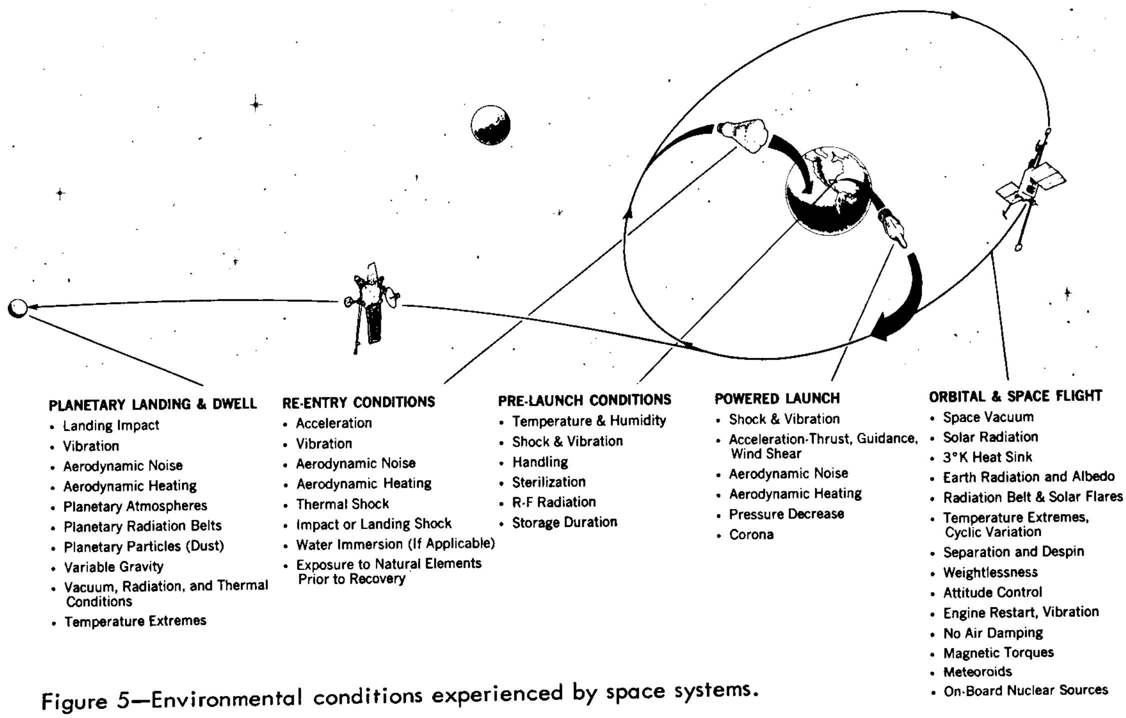


Figure 5—Environmental conditions experienced by space systems.

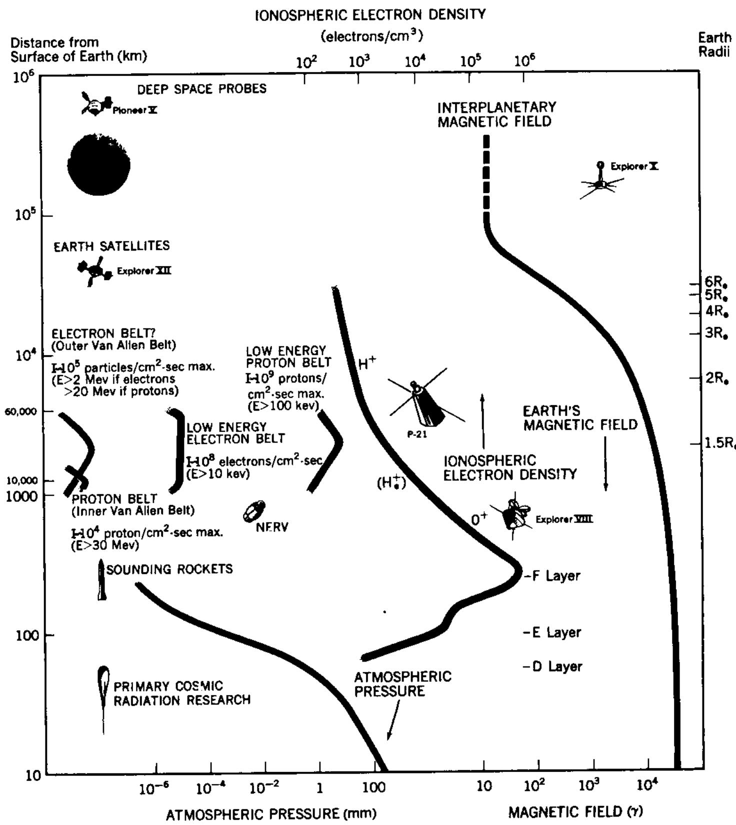


Figure 6—Properties of cislunar space.

Lifetime

The effective life of a satellite with a perigee of better than 150 miles is often dictated by its power supply and duty cycle. Where chemical batteries alone are used, the satellite life has averaged about 3 months. When a solar-cell rechargeable battery system is used, lifetimes of 1 year or more have been achieved with the average closer to 6 months. The most damaging effect is that of the enhanced radiation belt. Some details on selected satellite lifetimes are presented in Appendix A. It is noteworthy that the solar-powered transmitter of Vanguard 1 (1958 β 2) is still operating after nearly 5 years.

A TEST PHILOSOPHY

Reliability is an attribute of a system that must be designed into it. Testing can be used to test and evaluate the efficiency of a design. To some extent, testing can be used as a design tool to eliminate "weak links" in a system and thereby upgrade its quality. It can also be used to discover failure modes. Some of the popular concepts of testing are given in Table 3.

Table 3

Testing Concepts.

Type Tests	Purpose
Failure test	Design margin, failure mode
Life test	Fatigue limit, time-to-failure
Specification test	Qualification, production, acceptance
Special test	Investigate special conditions
Environmental test	Performance under environmental stress

Achieving confidence in the successful performance of a spacecraft poses a new type of reliability problem. The mathematical model so successfully employed in missile systems, while useful in highlighting critical system elements, provides little assurance for space systems. Spacecraft are one-of-a-kind, virtually hand-built systems. At most a prototype and two flight units are available. There are no "experience data" or failure mode information. The spacecraft as a system is very complex, utilizing thousands of components, and extends the state-of-the-technology both in design and fabrication. The sage advice of the statistician can be heard: "When you have only one sample, why try to predict its strength? — Just test it." Thus an *Environmental Test Philosophy* for spacecraft has been developed at the Goddard Space Flight Center (GSFC) for the purpose of determining the suitability for launch of a flight spacecraft (Reference 2).

THE ENVIRONMENTAL TEST PROGRAM

The ETP consists of a realistic series of environmental exposures that simulate the mission profile applied to both prototype and flight spacecraft in a configuration and mounting arrangement that duplicate space flight conditions as nearly as possible. The performance of the spacecraft is monitored either by the on-board telemetry or by means of special instrumentation. The performance of the spacecraft is continuously evaluated as calibrated stimuli are applied to the scientific experiments. Failures are diagnosed and corrected as they occur, thereby eliminating the "weak links" and continuously upgrading the quality level of the system. Upon completion of the expected life exposure or after accumulation of sufficient exposure to reduce the failure rate to a random level, the spacecraft is considered qualified. The foregoing process might be summarized by stating that the spacecraft is *launched* and *orbited* in the laboratory by means of an integrated series of environment simulation tests.

It is significant to note the fundamental difference in the test and evaluation process as it is commonly applied to a mass-produced military weapon system and to a one-of-a-kind space system. A comparison is shown in Table 4.

Table 4
Test and Evaluation Objectives.

Military System	Space System
1. Performance tests To demonstrate system operability under environmental conditions	1. Performance tests To demonstrate system operability under environmental conditions
2. Evaluation of design disclosure documents (dwgs., spec., manuals)	2. Evaluation of interface problems between actual subsystems
3. Evaluation of mass producibility and production lot characteristics	3. Evaluation of single sample with continuous upgrading
4. Classification of defects	4. Redesign, repair, or replacement of defective hardware
5. Evaluation of performance data to establish statistical limits for user	5. Training of launch team and data acquisition group in individual characteristics of system
6. System evaluation for feedback into future designs	6. Systems evaluation for feedback into future designs

One element contributing to the success of the ETP in spacecraft development has been the establishment of the environmental specification *early* in the project development cycle. This can generally be accomplished after the mission and the vehicle have been selected.* This specification gives the designer a specific and tangible goal to work toward; he knows when he has "cleared the hurdle" and thus places a finite end to the development cycle. However, this also means that the environmental test must be valid and based on an intelligent and realistic interpretation of measured data. In the GSFC program an attempt is made to measure new environmental data with each launch to provide a basis for updating and providing timely test specifications.

Establishment of environmental test levels for a system yet to be designed and for a mission into space is very vexing. We must be conservative to cover the unexpected and unknown, and yet be realistic so that the design and development can be accomplished within the restraints of the schedule, budget, and state-of-the-art. For *prototype systems* in which qualification of a design is the main

*"General Environmental Test Specification for Delta Launched Spacecraft," NASA Goddard Space Flight Center, System Evaluation Branch Specification No. G-2-000.

objective, test levels have been set at 1-1/2 times the worst conditions expected in flight. *Flight systems* are tested for acceptance at the worst conditions expected, compatible with the mission profile. This philosophy recognizes that some of the flight system's useful life is used by the these ground tests, but reduced longevity is considered a prudent tradeoff to insure against infant mortality. Added confidence in the design and assurance that fatigue failures will not be critical are achieved by running the prototype system tests for twice the duration of the flight unit tests. Sometimes the prototype unit is cycled through the test series for a number of cycles to establish failure modes and time-to-failure history.

The practical and specific application of the foregoing philosophy might be illustrative. For vibration tests the expected measured frequency range is covered for both prototype and flight units. The amplitude (g's) is set at the average $+2\sigma$ (95 percent point) value where several measurements are available; otherwise, the worst case projected from similar vehicles is assumed for the flight unit. This amplitude value is increased 50 percent for prototype units; and the duration is twice the flight unit value, which is based on approximate flight time or a sweep rate that will allow a resonant condition to achieve at least 95 percent of its peak amplitude.

While the application of this philosophy to the launch environments is fairly "straightforward," there are some difficulties with the orbital environments, such as space vacuum, solar simulation, and the 4°K heat sink of space. Likewise, it is impractical to test for the expected satellite lifetime. This has lead to the formulation of a failure model as shown in Figure 7. The principal factor in this

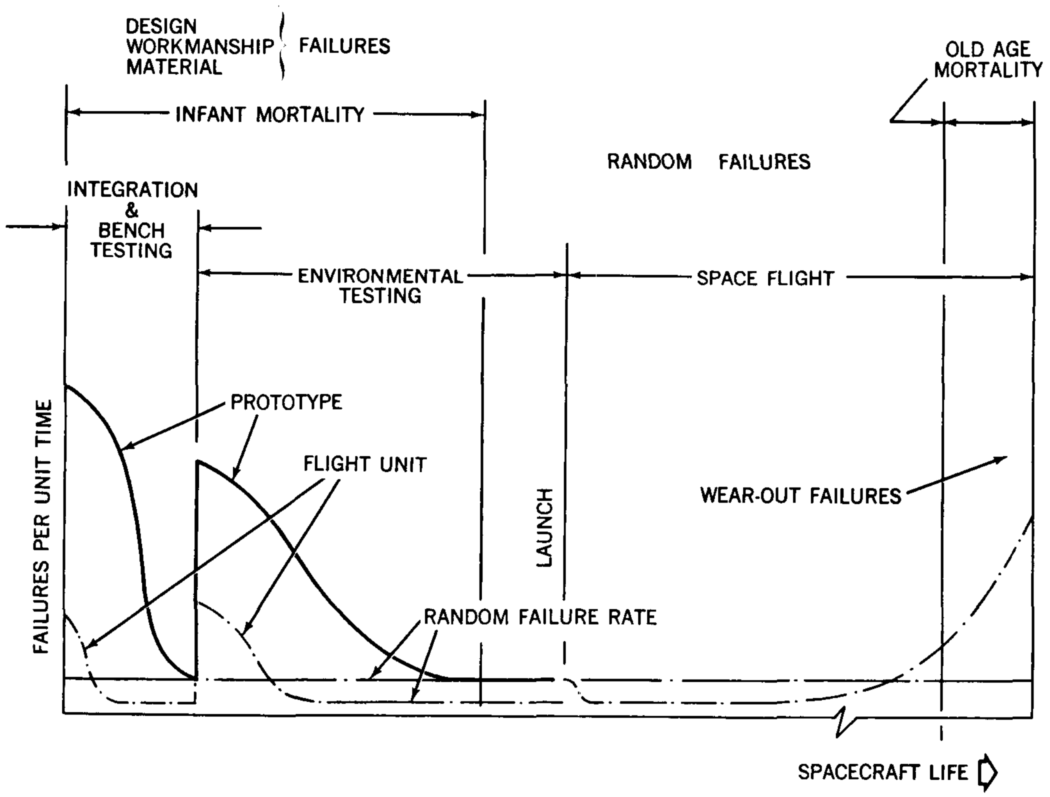


Figure 7—Failure patterns.

model is the reduction of failures under environmental tests until some random rate is reached. Also, the curves suggest that the failure rate is more severe for the prototype than for the flight unit, as would be expected from the more severe environmental stress levels used. It is current practice to expose the spacecraft to a test that permits thermal balance of a predetermined part of the system under the best attainable vacuum conditions, which must be 1×10^{-5} torr or better. This thermal-vacuum test is conducted for both the "hot" and "cold" calculated orbital temperature extremes. This temperature is arbitrarily raised and lowered 10° C for the prototype units. The length of the test should be consistent with the failure model, and has often been set as 3 days hot and 2 days cold, or a total of 5 days. The prototype is often tested for 7 days or more. Sufficient experience to evaluate the appropriateness of these choices is just now being accumulated. Reference 3 treats this problem in detail and suggest that this type test should be lengthened to 4 days hot and 4 days cold.

The space environments of meteorites and energetic particles are known to be particularly damaging; however, facility limitations have precluded their use in environmental test programs. In general these effects have been treated and allowed for on an analytical basis or by extrapolation of test results on materials and components. For example, it has been quite common to shield solar cells from radiation damage by means of glass covers of varying thickness up to 60 mils.

TYPICAL TEST PROGRAM

A typical environmental test program for a spacecraft includes background information about the mission requirements, the launch vehicle, the spacecraft and its functions, and the data handling systems. Detailed information is given on the environmental tests, the spacecraft checkout procedures, the test schedule, and the data collection procedures for both the on-board telemetry and special instrumentation.

The environmental exposures are normally applied in a sequence consistent with major events in the mission profile, such as prelaunch operations, launch, separation and injection, and orbital flight. A typical sequence is shown as Table 5.

Table 5

Typical Environmental Test Sequence.

1.	Pyrotechnic RF hazard
2.	Leak test for hermetically sealed units
3.	Static and dynamic balance
4.	Mass property determinations (wt, c.g., M=I)
5.	Spin & paddle boom or antenna deployment
6.	Temperature and humidity
7.	Shock
8.	Vibration and acoustic
9.	Steady state acceleration
10.	Thermal-vacuum and corona check
11.	Solar simulation and/or solar power check
12.	Magnetic check
13.	Antenna pattern and RF spectrum check

In addition, there may be several tests of a specialized nature dependent on the particular spacecraft or mission. Tests of this type could include sterilization, radiation damage, life tests, ordnance safety tests, structural tests, atmospheric heating tests, shroud fit, ejection and contamination test, guidance and control tests, and pressurization tests.

One of the really challenging tasks of the *Space Age* is completing the environmental test program for a spacecraft on a schedule that allows it to be joined to the launch vehicle and successfully launched. Normally this process may have up to 6 months allocated to it (Figure 8); however, since this is the last major function before launch site checkout, it often must be accomplished in 6 weeks or less. This places a premium on a properly planned program: It means that the required facilities must be available and thoroughly checked out. It means that each participant in the program must be thoroughly trained in his job and know the lines of authorities and responsibilities.

It is difficult to generalize the manpower and dollar costs of such programs. In fact the necessary data whereby a meaningful analysis can be made are just being accumulated. As a point of reference, manpower requirements for the environmental test program range between 15 and 25 percent of the total for the project development. On a recent satellite project in the 100 to 150 pound class the manpower requirements totaled 15 direct man-years of effort. To date, the dollar cost of the spacecraft environmental test programs has been less than 10 percent of the irrecoverable cost of the spacecraft launch. It is estimated that the in-orbit cost of a Thor-Delta launched spacecraft is $10 million. Included in the 10 percent figure cited is the prorated cost of spacecraft test facilities distributed over about 20 launches and 10 years of time.

It is very essential that a modern, well-equipped environmental test laboratory be available to carry out the type of program discussed. The Goddard Space Flight Center has just completed such a laboratory, which has a capitalized cost of about $15 million. It makes available nearly 3 acres of

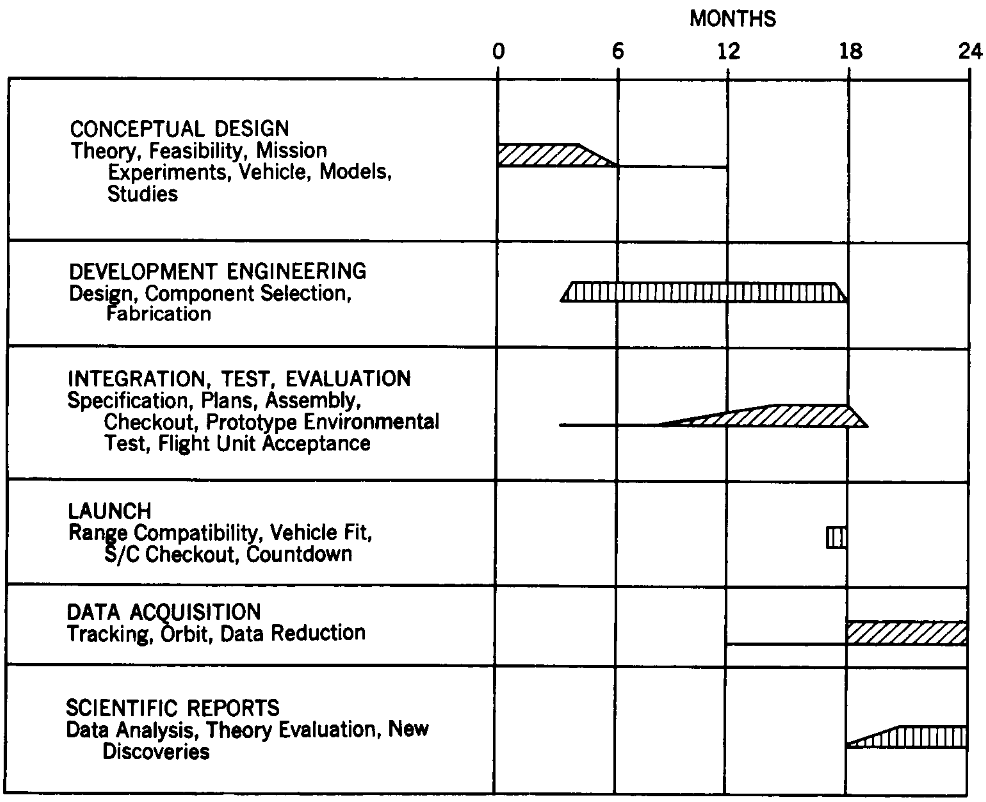


Figure 8—Scientific satellite development cycle.

air-conditioned, dust-free working area including office space. It has been designed to handle spacecraft weighing up to 4000 pounds with a maximum dimension of 10 feet in diameter by 15 feet in length. Centralized data handling facilities including digital computers are available for rapid processing of spacecraft data. Some typical views of this laboratory are shown in Figures 9, 10, and 11.

SPACECRAFT FAILURE DISTRIBUTION

A review of scientific satellite failures that have been detected by means of environmental test programs has been made for the calendar year 1962. This review of 114 failures, while not exhaustive, is believed to be representative of results that can be achieved. Five satellites were chosen for this review, all of which were launched and successfully performed in space during 1962. These satellites were chosen to represent several factors that might influence their complexity. For example, weights varied from less than 100 to over 300 pounds; three launch vehicles were represented; the scientific disciplines represented by the on-board experiments covered electron density; galactic noise; corpuscular, solar, and cosmic radiation; magnetic fields; ionospheric relations; and communication experiments. The telemetry systems were typically PFM, although one system included traveling wave tubes. Only one of the systems used batteries exclusively; the other four included

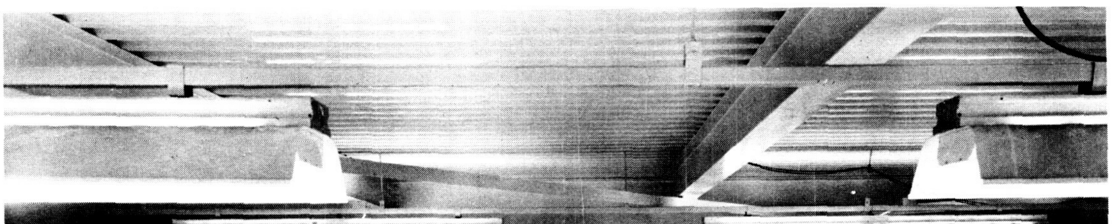


Figure 9—Spacecraft test facility at GSFC.

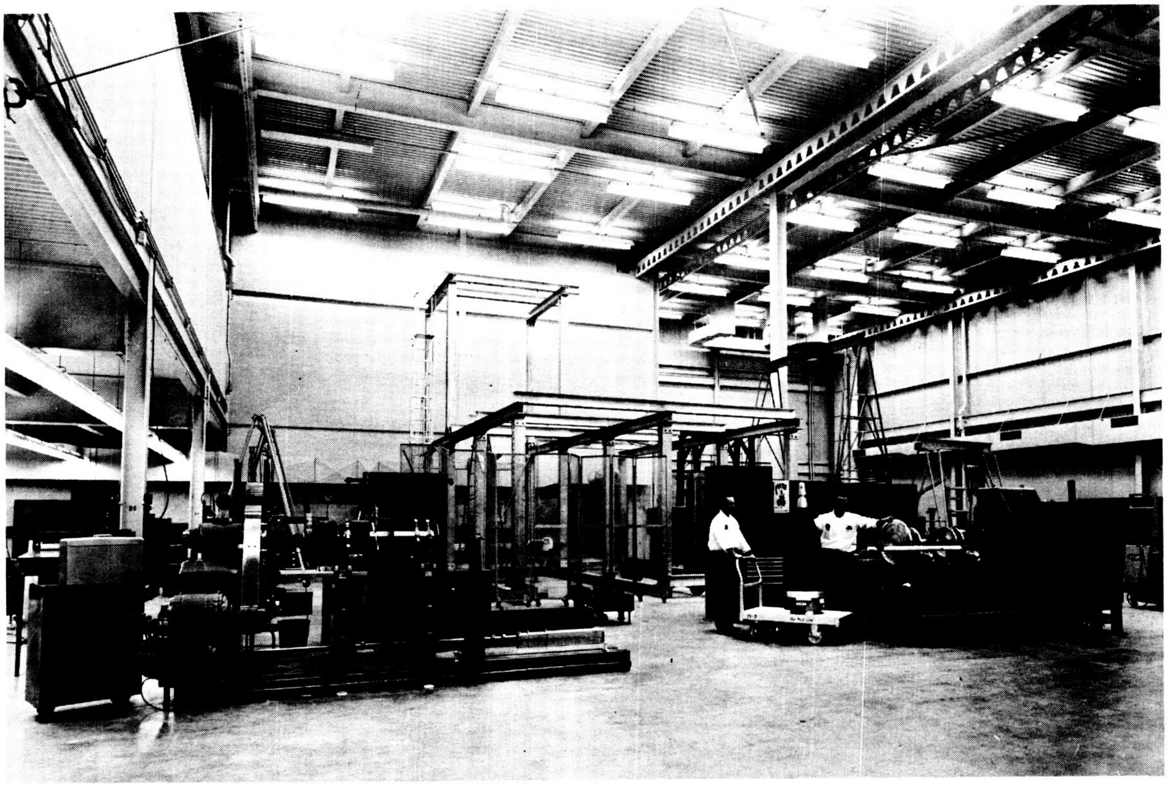


Figure 10—Mechanical test area.

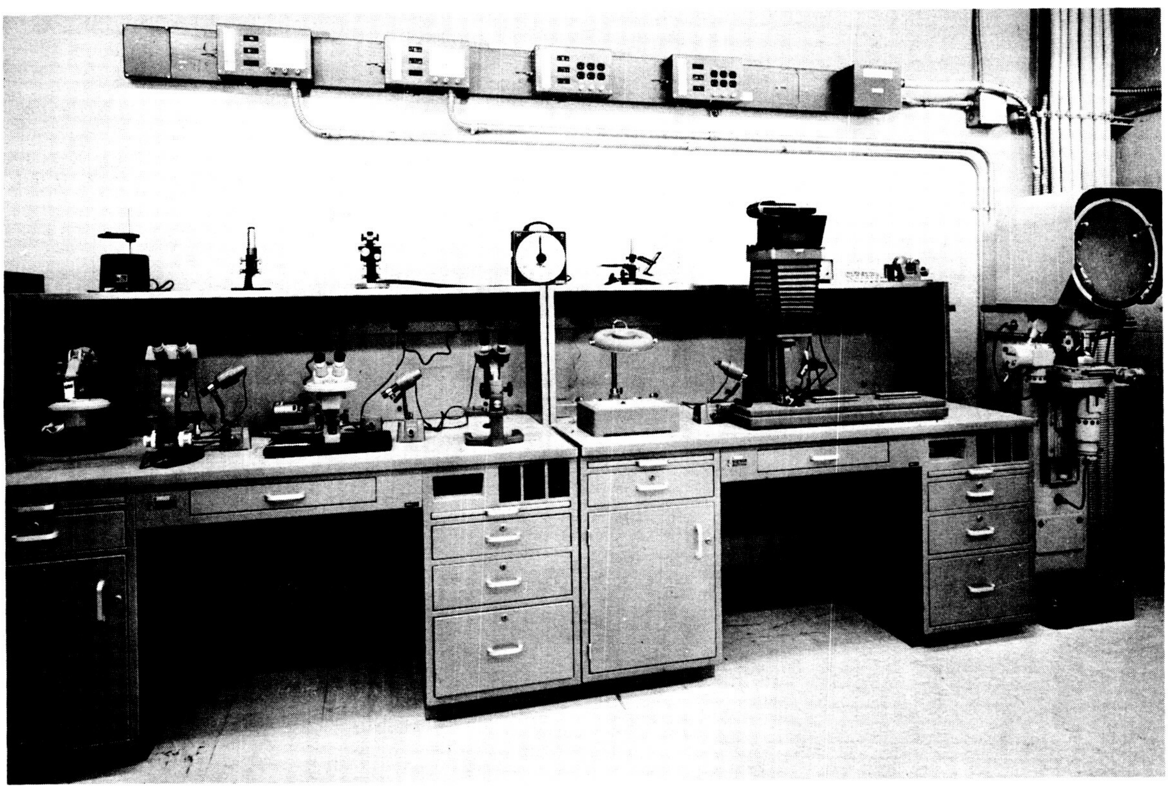


Figure 11—Failure analysis laboratory.

solar cells for power. The satellites reviewed include those developed by NASA, by industry, and through international cooperation. They all, however, were tested under the same philosophy expressed in this paper.

Detailed statistics will be found in Tables 6 and 7 (also see Figure 12). Some salient observations are that the ratio of electrical to mechanical failures is 4:1 (80 percent vs. 20 percent). The mechanical problems were chiefly concerned with antenna design, subsystem mounting, and local resonances. Stronger and stiffer designs, together with damping (often by potting), were general solutions to these problems. Electrical problems were often erratic and spurious, requiring much

Table 6

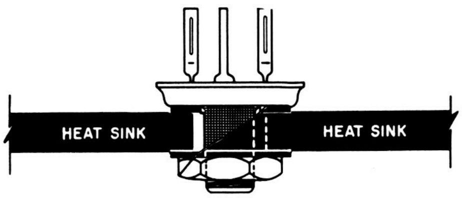
Failure Distribution by Spacecraft.

Spacecraft	Weight (lb)	Vehicle	Failures During Test					
			Electrical		Mechanical		Total	
			no.	%	no.	%	no.	%
A	94	Scout	10	71	4	29	14	12
B	170	Delta	15	83	3	17	18	16
C	86	Delta	18	78	5	22	23	20
D	150	Delta	42	86	7	14	49	43
E	310	Thor-Agena	6	60	4	40	10	9
		Total	91	80	23	20	114	100

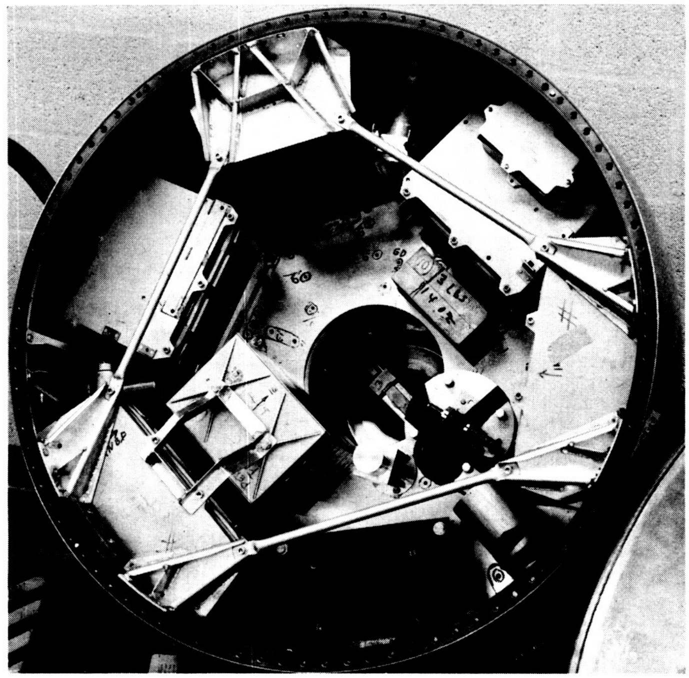
Table 7
Failure Distribution by Test Condition.

Failure Category	Failure During Test*															
	Electrical							Mechanical							Total	
	A	B	C	D	E	Total		A	B	C	D	E	Total			
						no.	%						no.	%	no.	%
Checkout	-	2	3	5	2	12	13	-	-	1	4	1	6	26	18	16
Vibration	7	5	3	4	1	20	22	4	3	3	1	3	14	61	34	30
Temperature	-	1	1	-	1	3	3	-	-	-	-	-	-	-	3	3
Vacuum	-	1	3	1	-	5	5	-	-	-	-	-	-	-	5	4
Thermal-vacuum	3	6	8	32	2	51	56	-	-	1	2	-	3	13	54	47
TOTAL	10	15	18	42	6	91	100	4	3	5	7	4	23	100	114	100

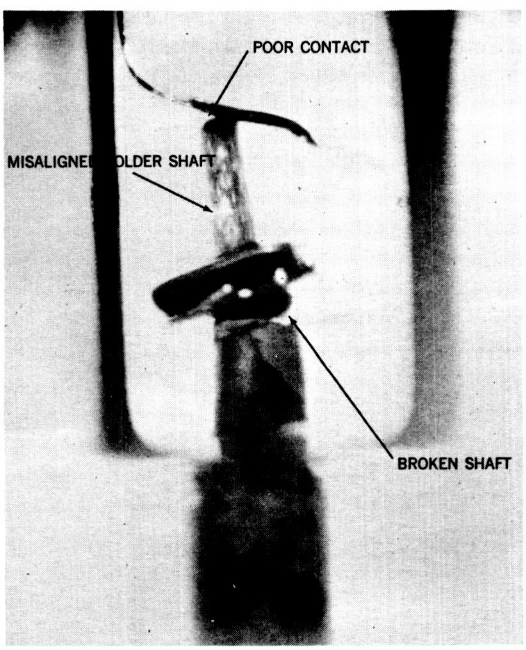
*Test conditions for spacecraft A, B, C, D, and E.



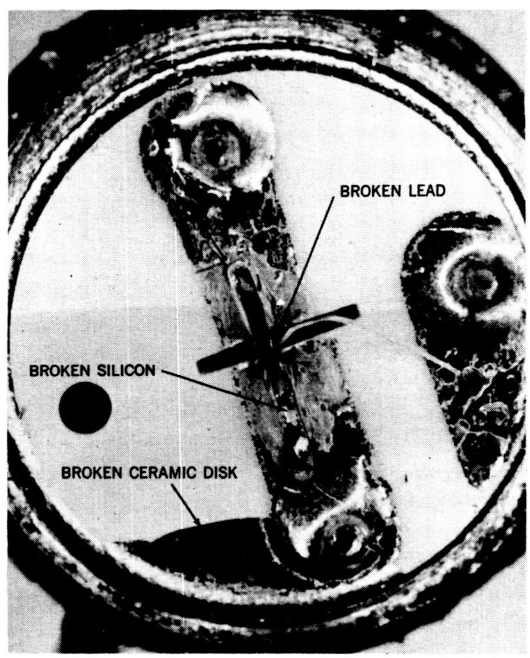
TYPICAL ELECTRICAL FAILURE (THERMAL RUNAWAY) REVEALED DURING THERMAL-VACUUM TESTS AND INADEQUATE HEAT SINK OR POOR THERMAL CONTACT ARE COMMON FAILURE CAUSES



INTERNAL BRACING AND STIFFENERS REDUCING RESONANT AMPLITUDE BY FACTOR OF 10



DIODE WORKMANSHIP FAILURE REVEALED DURING TEMPERATURE TEST



MECHANICAL FAILURE OF TRANSISTOR DURING VIBRATION

Figure 12—Failures in spacecraft.

troubleshooting. Solid state components were often found to be faulty. Local overheating was often corrected by providing improved heat sinks and heat conduction paths. The failure distribution seems reasonably consistent among the satellites. While not evident from the information presented, there appears to be a general relation pointing toward increasing failures with satellite complexity and development group inexperience. This result would be expected.

Nearly one-half of all the failures reviewed occurred during the thermal-vacuum test, which simulated space conditions. However, nearly one-sixth of the failures occurred during checkout, and about one-third during vibration. One observation to be made from these data is the importance of completing the entire system and checking it out early in the project life. One-sixth of the errors noted here are primarily indicative of the interaction of subsystems and the many interface problems. Cabling and connectors are particular offenders at this stage of checkout. The primary item to note again is that each of these failures was detected, corrected, tested, and evaluated. The final result in space was a successful satellite. One unanswered question is whether there is some other, or more effective, mechanism whereby these failures can be detected earlier in the project life.

OBSERVATIONS AND CONCLUSIONS

The most important element in achieving satellite reliability is the quality of the *project people* and their proper motivation. Most failures can ultimately be traced to some individual who failed to appreciate the importance of details. Seldom has it been found that there was a basic material deficiency. Personal attitudes, work habits, training, and management policies are all vitally important. However, written directives are poor substitutes for technical competence. A few axioms, developed from the GSFC space experience, might prove helpful in the experience feedback cycle:

PEOPLE are the most important product.
There is no substitute for firsthand knowledge.
Retain responsibility from concept through completion.
Be a little suspicious.
Even the best designs have "weak links."
Be pessimistic about success until achieved.
Mistakes are disastrous in one-of-a-kind programs.
Reliability and complexity abhor each other.
A single failure should not defeat a mission.
Minimize the required number of sequential events.
Do not launch mistakes; prove corrective actions by ground tests.
Last-minute "improvements" have a 100 percent failure rate.
Qualify all flight units by full system tests.
A qualified flight system is held inviolate to change or modification.

The success of the environmental test program at GSFC is attributed to the high quality of the people conducting the program; the excellent facilities available; and the favorable, responsive, and encouraging attitude of NASA management. The importance of having competent, professional environmental engineers—not machine operators—plan and conduct this program cannot be overstressed.

The benefits derived from an environmental test program conducted on a full system include the verification of novel or unproven hardware, elimination of weak links, discovery of unexpected interactions, qualification of the flight system, training of launch personnel, and development of future design guidance.

The large cost and national importance of the space program has set the goals of high reliability and successful performance for each launch in the space program. These goals have been achieved for scientific satellites by means of a comprehensive test program duplicating operational and space environment conditions on each flight system prior to launch.

REFERENCES

1. New, J. C., "Scientific Satellites and the Space Environment, " NASA Technical Note D-1340, June 1962.

2. Boeckel, J. H., "The Purposes of Environmental Testing for Scientific Satellites, "NASA Technical Note D-1900, 1963.

3. Timmins, A. R., and Rosette, K. L., "Experience in Thermal-Vacuum Testing Earth Satellites at Goddard Space Flight Center," NASA Technical Note D-1748, 1963.

Appendix A

Satellite History

Goddard Space Flight Center Satellites and Space Probe Projects

As of December 1962

Designation	DATE Launch	DATE Silent	Launch Vehicle & Site	Objectives	Instrumentation	Period Minutes	Orbital Elements Perigee Statute Miles	Orbital Elements Apogee Statute Miles	Project Manager & Project Scientist	Experiment	Experimenter	Affiliation	Remarks
EXPLORER VI 1959 Delta I (S–2)	Aug. 7, 1959	Oct. 6, 1959	Thor-Able AMR	To measure three specific radiation levels of Earth's radiation belts; test scanning for Earth's cloud cover; map Earth's magnetic field; measure micrometeorites; study behavior of radiowaves.	Equipment to measure radiation levels; TV-type scanner; micrometeorite detector; two types of magnetometer and devices for space communication experiments.	12½ hours	156	26,357	Dr. John C. Lindsay Dr. John C. Lindsay	Triple coincidence telescopes	J. A. Simpson C. Y. Fan P. Meyer	U. of Chicago	Orbit achieved. All experiments performed. First complete televised cloud-cover picture was obtained. Detected large ring of electrical current circling Earth; complete map of Van Allen radiation belt obtained. Weight: 142 lb Power: Solar Life: 2 months
										Scintillation counter	T. A. Farley Allen Rosen C. P. Sonnett	Space Technology Laboratories	
										Ionization chamber Geiger counter	J. Winckler	U. of Minn.	
										Spin-coil magnetometer	E. J. Smith D. L. Judge	STL	
										Fluxgate magnetometer	P. J. Coleman	STL	
										Aspect sensor		STL	
										Image-scanning television system		STL	
										Micrometeorite detector		Cambridge Research/STL	
VANGUARD III 1959 Eta	Sept. 18, 1959	Dec. 12, 1959	Vanguard AMR	To measure the Earth's magnetic field, x-radiation from the sun, and several aspects of the space environment through which the satellite travels.	Proton precisional magnetometer, ionization chambers for solar xrays, micrometeor detectors, and thermistors.	130	319	2329		Magnetometer	J. P. Heppner	GSFC	Orbit achieved. Provided comprehensive survey of earth magnetic field over area covered; surveyed location of lower edge of Van Allen Radiation Belt. Accurate count of micrometeorite impacts. Weight: 100 lb including attached 3rd stage. Power: Battery Life: 85 days
										Ionization Chambers	H. Friedman	NRL	
										Environmental Measurements	H. E. LaGow	GSFC	
EXPLORER VII (S–1a)	Oct. 13, 1959	Aug. 24, 1961	Juno II AMR	Variety of experiments, including solar ultraviolet; xray; cosmic ray, Earth radiation and micrometeor experiments.	Sensors for measurements of Earth-Sun heat balance; Lyman-alpha and x-ray solar radiation detectors; micrometeor detectors, Geiger-Mueller tubes for cosmic-ray count; ionization chamber for heavy cosmic rays.	101.33	342	680	H. LaGow	Thermal radiation balance	V. Suomi	U. of Wisc.	Orbit achieved. Provided significant geophysical information on radiation and magnetic storms; demonstrated method of controlling internal temperatures; first micrometeorite penetration of a sensor in flight. Weight: 91.5 lb Power: Solar Life: 26 months
										Solar x-ray and Lyman-alpha	H. Friedman R. W. Kreplin T. Chubb	NRL	
										Heavy cosmic radiation	G. Groetzinger P. Schwed M. Pomerantz	Martin Co. Bartrol Research	
										Radiation and solar-proton observation	J. Van Allen G. Ludwig H. Whelpley	St. U. of Iowa	
										Ground-based ionospheric observations	G. Swenson Dr. C. Little G. Reid O. Villard, Jr. W. Ross W. Dyke	U. of Illinois Nat. Bu. of Stand. U. of Alaska Stanford U. Penn State U. Linfield Res. Inst.	
										Micrometeorite penetration experiment	H. LaGow	GSFC	

Designation	DATE Launch	DATE Silent	Launch Vehicle & Site	Objectives	Instrumentation	Period Minutes	Orbital Elements Perigee Statute Miles	Orbital Elements Apogee Statute Miles	Project Manager & Project Scientist	Experiment	Experimenter	Affiliation	Remarks
PIONEER V 1960 Alpha	Mar. 11, 1960	June 26, 1960	Thor-Able AMR	Investigate interplanetary space between orbits of Earth and Venus, test extreme long range communications, study methods for measuring astronomical distances.	High intensity radiation counter, ionization chamber Geiger-Mueller tube to measure plasmas, cosmic radiation, and charged solar particles. Magnetometer and micrometeorite temperature measurements.	311.6 days	Perihelion 74.9 million from sun	Aphelion 92.3 milion from sun	Dr. John C. Lindsay Dr. John C. Lindsay	Triple coincidence, proportional counter, cosmic ray telescope	J. Simpson	U. of Chicago	Highly successful exploration of interplanetary space between orbits of Earth and Venus; established communication record of 22.5 million miles on 6/26/60; made measurements of solar flare effects, particle energies and distribution, and magnetic field phenomena in interplanetary space. Weight: 94.8 lb Power: Solar Life: 3 months
										Search-coil magnetometer and photo electric cell aspect indicator	D. Judge	STL	
										Ionization chamber and G-M tube	J. Winckler	U. of Minn.	
										Micrometeorite counter	E. Manring	AFCRC	
TIROS I Beta 1960 (A–1)	April 1, 1960	June 12, 1960	Thor-Able AMR	Test of experimental television techniques leading to eventual worldwide meteorological information system.	One wide and one narrow angle camera, each with tape recorder for remote operation. Picture data can be stored on tape or transmitted directly to ground stations.	99.1	428.7	465.9	W. G. Stroud (GSFC) H. Butler (Army)	TV camera systems (2)			Provided 1st global cloud-cover photographs (22,952 total) from near circular orbit. Weight: 270 lb Power: Solar Life: 72 days
ECHO I 1960 Iota	Aug. 12, 1960	Still in Orbit	Thor-Delta AMR	Place 100-foot inflatable sphere into orbit.	Two Minitrack tracking Beacons on sphere.	118.3	945	1049	Robert J. Mackey				Demonstrated use of radio reflector for global communications, numerous successful transmissions. Visible to the naked eye. Weight: 132 lb (including inflation powder). Power: Passive Life: Still in Orbit
EXPLORER VIII 1960 Xi (S–30)	Nov. 3, 1960	Dec. 28, 1960	Juno II AMR	Investigation of the ionosphere by direct measurement of positive ion and electron composition; collect data on the frequency momentum and energy of micrometeorites impacts; establish attitude of the base of the exosphere.	RF impedance probe using a 20-foot dipole sensor; single grid ion trap; four multiplegrid ion traps; Langmuir probe experiment; rotating shutter electric field meter; micro plier; micrometeorite microphone; thermistors for reading internal and surface temperatures of the space craft; and despin mechanisms to reduce spin from 450 to 30 rpm.	112.7	258	1423	Robert E. Bourdeau Robert E. Bourdeau	RF impedance	J. Cain	GSFC	Measured the electron density, temperature, ion density and composition, and charge on the satellite in the upper ionosphere. The micrometeorite influx rate was measured. Weight: 90.14 lb Power: Battery Life: 55 days
										Ion traps	R. Bourdeau G. Serbu E. Whipple J. Donnelly	GSFC	
										Langmuir probe	R. Bourdeau G. Serbu E. Whipple J. Donnelly	GSFC	
										Rotating-shutter electric field meter	J. Donnelly	GSFC	
										Micrometeorite photomultiplier	M. Alexander K. McCracken O. Berg	GSFC	
										Micrometeorite microphone	M. Alexander K. McCracken	GSFC	

Goddard Space Flight Center Satellites and Space Probe Projects—Cont.

As of December 1962

Designation	DATE Launch	DATE Silent	Launch Vehicle & Site	Objectives	Instrumentation	Period Minutes	Orbital Elements Perigee Statute Miles	Orbital Elements Apogee Statute Miles	Project Manager & Project Scientist	Experiment	Experimenter	Affiliation	Remarks
TIROS II 1960 Pi I (A–2)	Nov. 23, 1960	Feb. 7, 1961	Delta AMR	Test of experimental television techniques and infrared equipment leading to eventual world-wide meteorological information system.	Includes one wide and one narrow angle camera, each with tape recorder for remote operation; infrared sensors to map radiation in various spectral bands; attitude sensors; experimental magnetic orientation control.	98.2	406	431	Dr. R. Stampfl	TV camera system (2). Widefield radiometer experiment. Scanning radiometer experiment.			Orbit achieved. Narrow-angle camera and IR instrumentation sent good data. Transmitted 36,156 pictures. Still operative. Weight: 277 lb Power: Solar Life: 76 days
EXPLORER IX 1961 Delta I (S–56a)	Feb. 16, 1961	Passive Satellite	Scout Wallops Island	To study performance, structural integrity and environmental conditions of Scout research vehicle and guidance controls system. Inject inflatable sphere into Earth orbit to determine density of atmosphere.	Radio beacon on balloon and in fourth stage.	118.3	395	1605					Vehicle functioned as planned. Balloon and fourth-stage achieved orbit. Transmitter on balloon failed to function properly requiring optical tracking of balloon. Weight: 80 lb Power: Passive Life:
EXPLORER X 1961 Kappa (P–14)	Mar. 25, 1961	Mar. 27, 1961	Thor-Delta AMR	Gather definite information on earth and interplanetary magnetic fields and the way these fields affect and are affected by solar plasma.	Includes rubidium vapor magnetometer, two fluxgate magnetometers, a plasma probe, and an optical aspect sensor.	112 hours	100	186,000	Dr. J. P. Heppner Dr. J. P. Heppner	Rubidium vapor magnetometer & fluxgate magnetometers Plasma probe Spacecraft attitude experiment	J. P. Heppner T. L. Skillman C. S. Scearce H. Bridge F. Scherb B. Rossi J. Albus	GSFC MIT GSFC	Probe transmitted valuable data continuously for 52 hours as planned. Demonstrated the existence of a geomagnetic cavity in the solar wind and the existence of solar proton streams transporting solar interplanetary magnetic fields past the earth's orbit. Weight: 79 lb Power: Battery Life: 52 hr.
EXPLORER XI 1961 Nu I (S–15)	Apr. 27, 1961	Dec. 6, 1961	Juno II AMR	Orbit a gamma ray astronomy telescope satellite to detect high energy gamma rays from cosmic sources and map their distribution in the sky.	Gamma ray telescope consisting of a plastic scintillator, crystal layers, and a Cerenkov detector; sun and earth sensors; micrometeorite shields; temperature sensor; damping mechanism.	108.1	304	1113.2	Dr. J. Kupperian, Jr. Dr. J. Kupperian, Jr.	Gamma ray telescope	W. Kraushaar G. Clark	MIT	Orbit achieved. Detected first gamma rays from space. Directional flux obtained. Disproved one part of "steady state" evolution theory. Weight: 82 lb Power: Solar Life: 7 months
TIROS III 1961 Rho I (A–3)	July 12, 1961	Dec. 4, 1961	Thor-Delta AMR	Develop satellite weather observation system; obtain photos of Earth's cloud cover for weather analysis; determine amount of solar energy absorbed, reflected and emitted by the Earth.	Two wide-angle cameras, two tape recorders and electronic clocks; infrared sensors, five transmitters, attitude sensors, magnetic attitude coil.	100.4	461.02	506.44	R. Rados	Omnidirectional radiometer Widefield radiometer experiment, scanning radiometer experiment TV cameras (2)	V. Suomi	U. of Wisc.	Orbit achieved. Cameras and IR instrumentation transmitted good data. Transmitted 35,033 pictures. First hurricane covering international program. Weight: 285 lb Power: Solar Life: 145 days

Designation	DATE Launch	DATE Silent	Launch Vehicle & Site	Objectives	Instrumentation	Period Minutes	Orbital Elements Perigee Statute Miles	Orbital Elements Apogee Statute Miles	Project Manager & Project Scientist	Experiment	Experimenter	Affiliation	Remarks
EXPLORER XII 1961 Upsilon I (S-3)	Aug. 15, 1961	Dec. 6, 1961	Thor-Delta AMR	Investigate solar wind, interplanetary magnetic fields, distant portions of Earth's magnetic field, energetic particles in interplanetary space and in the Van Allen Belts.	Ten particle detection systems for measurement of protons and electrons and three orthogonally mounted fluxgate sensors for correlation with the magnetic fields, optical aspect sensor, and one transmitter. Telemetry is PFM and transmits continuously.	26.45 hours	180	47,800	P. Butler Dr. F. McDonald	Proton analyzer Magnetometer Cosmic ray Ion-electron detector Solar cell	M. Bader L. Cahill B. O'Brien F. B. McDonald L. Davis G. Longanecker	Ames Research Center U. of New Hampshire St. U. of Iowa GSFC GSFC GSFC	Orbit achieved; all instrumentation operated normally. Ceased transmitting on Dec. 6, 1961, after sending 2568 hours of real-time data. Provided significant geophysical data on radiation and magnetic fields. Weight: 83 lb Power: Solar Life: 4 months
EXPLORER XIII 1961 Chi	Aug. 25, 1961	Aug. 27, 1961	Scout Wallops Island	Testing performance of the vehicle and guidance; investigation, nature and effects on space flight of micrometeoroids.	Micrometeoroids impact, detectors, transmitters.	97.5	74	722	C. T. D'Aiutolo	A cadmium sulfate photoconductor experiment. A wire grid experiment.	M. W. Alexander L. Secretan	GSFC	Orbit was lower than planned. Re-entered August 27, 1961. Weight: 187 lb. including 50-lb 4th stage and 12-lb transition section. Power: Solar Life: 2 days
P21 ELECTRON DENSITY PROFILE PROBE (P-21)	Oct. 19, 1961	Oct. 19, 1961	Scout Wallops Island	To measure electron densities and to investigate radio propagation at 12.3 and 73.6 Mc under daytime conditions.	Continuous wave propagation experiment for the ascent portion of the trajectory, and an RF probe technique for the descent.		N/A	N/A 4261	John E. Jackson Dr. S. J. Bauer	RF probe	H. Whale	GSFC	Probe achieved altitude of 4261 miles and transmitted good data. Electron density was obtained to about 1500 miles, making the first time such measurements have been taken at this altitude. Weight: 94 lb Power: Battery Life: Hours
TIROS IV 1962 Beta (A-9)	Feb. 8, 1962	June 19, 1962	Delta AMR	Develop principles of weather satellite system; obtain cloud and radiation data for use in meteorology.	Two TV camera systems with clocks and recorders for remote pictures, infrared sensors, heat budget sensors, magnetic orientation control horizon sensor, north indicator.	100.4	471	525	R. Rados	Omni-directional radiometer. Widefield radiometer experiment. Scanning radiometer experiment. TV camera systems (2)	V. Suomi	U. of Wisc.	Orbit achieved. All systems transmitting good. Tegea Kinoptic lens used on one camera. Elgeet lens on the other. Support to Project Mercury. Weight: 285 lb Power: Solar Life: 131 days

Goddard Space Flight Center Satellites and Space Probe Projects—Cont.

As of December 1962

Designation	DATE Launch	DATE Silent	Launch Vehicle & Site	Objectives	Instrumentation	Period Minutes	Orbital Elements Perigee Statute Miles	Orbital Elements Apogee Statute Miles	Project Manager & Project Scientist	Experiment	Experimenter	Affiliation	Remarks
ORBITING SOLAR OBSERVATORY OSO—1 1962 Zeta (S—16)	Mar. 7, 1962	Active	Delta AMR	Placed satellite in Earth orbit to measure solar electromagnetic radiation in the ultra-violet, x-ray, and gamma ray regions; investigated effect of dust particles on surfaces of spacecraft.	Devices to conduct 13 different experiments for study of solar electromagnetic radiation; investigate dust particles in space and thermo radiation characteristics of spacecraft surface materials.	96.15	343.5	369	Dr. John C. Lindsay	X-ray spectrometer	W. Behring W. Neupert	GSFC	Orbit achieved. Experiments transmitting as programmed. Weight: 458 lb Power: Solar Life: Active
									Dr. John C. Lindsay	0.510 Mev gamma ray monitoring; 20—100 kev x-ray monitoring; 1—8A x-ray monitoring	K. Frost W. White	GSFC	
										Dust particle experiment	M. Alexander C. McCracken	GSFC	
										Solar radiation experiment, solar ultraviolet	W. White K. Hallam		
										Solar gamma rays, high energy distribution	W. White K. Frost	GSFC	
										Solar gamma rays, low energy distribution	J. R. Winkler L. Peterson	U. of Minn.	
										Solar gamma rays, high energy distribution	M. Savedoff G. Fazio	U. of Rochester	
										Neutron monitor experiment	W. Hess	U. of Calif.	
										Lower Van Allen belt	S. Bloom	U. of Calif.	
										Emissivity stability of surfaces in a vacuum environment	G. Robinson	Ames Research Center	
P21A ELECTRON DENSITY PROFILE PROBE (P—21A)	Mar. 29, 1962	Mar. 29, 1962	Scout Wallops Island	To measure electron density profile, ion density, and type of ions in the atmosphere.	A continuous wave propagation experiment to determine electron density and associated parameters of ionosphere. A swept frequency probe for direct measurements of electron density and a positive ion experiment to determine ion concentration under night-time conditions.		N/A	N/A 3910	John E. Jackson	CW propagation	S. Bauer	GSFC	Afforded night-time observations. Characteristics of the ionosphere differ drastically from daytime state when the temperature of the ionosphere is much cooler. See P-21 Weight: 94 lb Power: Battery Life: Hours
									Dr. S. J. Bauer	RF probe	H. Whale	GSFC	
										Ion traps	R. Bordeau E. Whipple J. Donnelly G. Serbu	GSFC	
ARIEL INTER-NATIONAL SATELLITE (UK 1) (S—51)	April 26, 1962	Active	Delta AMR	To study ionosphere and cosmic rays relation.	Electron density sensor, electron temperature gage, solar aspect sensor, cosmic ray detector, ion mass sphere, Lyman-alpha gages, tape recorder, x-ray sensors.	100.9	242.1	754.2	R. C. Baumann	Electron density sensor.			Orbit achieved. All experiments except Lyman-alpha transmitting as programmed. First international satellite. Contains six British experiments, launched by American Delta vehicle. Weight: 150 lb Power: Solar Life: Active
									Robert E. Bourdeau	Electron temperature gage.			
										Solar aspect sensor.			
										Cosmic ray detector.			
										Ion mass sphere.			
										Lyman-alpha gage.			

Designation	DATE Launch	DATE Silent	Launch Vehicle & Site	Objectives	Instrumentation	Period Minutes	Orbital Elements Perigee Statute Miles	Orbital Elements Apogee Statute Miles	Project Manager & Project Scientist	Experiment	Experimenter	Affiliation	Remarks
TIROS V 1962 Alpha Alpha One (A–50)	June 19, 1962	Active	Delta AMR	Develop principles of weather satellite system; obtain cloud-cover data and radiation data for use in meteorology.	Two TV camera systems with tape recorders for recording remote picture areas, infrared sensors, magnetic orientation control, horizon sensor, north indicator.	100.5	367	604	R. Rados	TV camera systems (2)			Launched at a higher inclination (58°) than previous TIROS satellites to provide greater coverage. Time of launch chosen to include normal hurricane season for South Atlantic. IR sensor inoperative, all other systems transmitting good. Weight: 285 lb Power: Solar Life: Active
TELSTAR NO. 1	July 10, 1962	Active	Delta AMR	Joint AT & T investigation of wide-band communications.	The system provides for TV, radio, telephone, and data transmission via a satellite repeater system.	157.8	592.6	3503.2	C. P. Smith, Jr.				Orbit achieved. Television and voice transmissions were made with complete success. Bell Telephone Laboratories provide spacecraft and ground stations facilities. Government to be reimbursed for cost incurred. Weight: 175 lb Power: Solar Life: Active
ALOUETTE SWEPT FREQUENCY TOPSIDE SOUNDER (S–27)	Sept. 29, 1962	Active	Thor Agena PMR	To measure the electron density distribution in the ionosphere at altitudes between 180 miles and 620 miles. To study for a period of a year the variations of electron density distribution with time of day and with latitude, under varying magnetic and auroral conditions; and with particular emphasis on high latitude effects. To determine electron densities in the vicinity of the satellite by means of galactic noise measurements, and to make observations of related physical phenomena; such as the flux of energetic particles.	A swept frequency pulsed sounder covering the frequency range 1.6 to 11.5 Mc.	105.4	620	638	John E. Jackson	Diurnal hour to hour change. Electron density. Ionization. Whistler experiment.			The Alouette satellite is a project of the Canadian Defense Research Board. The project is part of NASA's Topside Sounder Program. This will be NASA's first satellite to be launched from the Pacific Missile Range. 80.84 inclination Alouette is not spacecraft designed and built by any other country than the U.S. and USSR. Weight: 320 lb Power: Solar Life: Active
TIROS VI (A–51)	Sept. 18, 1962	Active	Delta AMR	To study cloud cover and earth heat balance; measurement of radiation in selected spectral regions as part of a program to develop meteorological satellite systems.	Two TV camera systems (78° and 104° lens), clocks and tape recorders for remote operation, infrared and attitude sensors, magnetic attitude coil.	98.73	425	442	R. Rados	Medium angle camera failed Dec. 1, 1962 after taking 1074 pictures.			Inclination 58.3°, velocity perigee 16,822, apogee 16,756. Weight: 300 lb Power: Solar Life: Active

Goddard Space Flight Center Satellites and Space Probe Projects—Cont.

As of December 1962

Designation	DATE Launch	DATE Silent	Launch Vehicle & Site	Objectives	Instrumentation	Period Minutes	Orbital Elements Perigee Statute Miles	Orbital Elements Apogee Statute Miles	Project Manager & Project Scientist	Experiment	Experimenter	Affiliation	Remarks
ENERGETIC PARTICLES SATELLITE *EXPLORER XIV* (S–3a)	Oct. 2, 1962	Active	Delta AMR	To describe the trapped corpuscular radiation, solar particles, cosmic radiation, and the solar winds, and to correlate the particle phenomena with the magnetic field observations.	An actagon-walled platform, fabricated from nylon honeycomb and fiber glass, houses most of the instruments, experiments, and electronics. The transmitter is located in the base of the spacecraft. A magnetometer package containing three orthogonally mounted magnetometers and calibration coils is located on a boom forward of the platform. Telemetry is PFM and transmits continuously.	37 hours (2185 minutes)	175	61,226	Paul G. Marcotte Dr. Frank B. McDonald	Cosmic ray experiment	F. McDonald	GSFC	Velocity of apogee 1507 mph, perigee *23,734 mph. Inclination* to Equator 33°.
										Ion detector experiment	L. Davis	GSFC	Weight: 86 lb
										Solar cell experiment	G. Longanecker	GSFC	Power: Solar
										Probe analyses	M. Bader	Ames	Life: Active
										Trapped radiation experiment	B. O'Brien	St. U. of Iowa	
										Magnetometer *experiment*	L. Cahill	U. of New Hampshire	
EXPLORER XV (S 3–b)	Oct. 27, 1962	Active	Delta AMR	To study new artificial radiation belt created by *nuclear explosions.*	Similar to Explorer XII.	5 hours *(C. 315* min)	195	10,950	Dr. John W. Townsend Dr. Wilmot Hess	Electron energy distribution	W. Brown V. Desai	Bell Telephone Laboratories	Good data received on artificial radiation belt.
										Omnidirectional detector	C. McIlwain	U. of Calif.	Weight: 100 lb
										Angular distributor	W. Brown	Bell Telephone Laboratories	Power: Solar
										Directional detector	C. Mc[redacted]wain	U. of Calif.	Life: Active
										Ion-electron detector	L. Davis	GSFC	
										Magnetic field experiment	*L. Cahill*	*U. of New* Hampshire	
										Solar cell gage	H. K. Gummel	Bell Telephone Laboratories	
RELAY (A–16)	Dec. 13, 1962	*Active*	*Delta* AMR	*To investigate wide-band* communications between ground stations by means of low-altitude orbiting space craft. Communications signal to be evaluated will be an assortment of television signals, multi-channel telephony and other communications.	The spacecraft will contain an active communications repeater to *receive* and retransmit communications between the U.S. and Europe, and an *experiment* to assess radiation damage to solar cells.	185.09	819.64	4612.18	Joseph Berliner Dr. R. C. Waddel	First TV transmission U.S. to France, Jan. 9, 1963			Wide-band Stations: Rumford, *Maine;* Pleumeur-Bodou, France; Goonhilly, England; Weilheim, W. Germany. Narrow-band *stations:* Nutley, *N.J.;* Rio de Janeiro, Brazil. Inclination 47.47°. Weight: 185 lb Power: Solar Life: Active

NASA-Langley, 1963 G-383